

ANNEX F

Methodology for Estimating CH₄ Emissions from Natural Gas Systems

The following steps were used to estimate methane emissions from natural gas systems.

Step 1: Calculate Emission Estimates for Base Year 1992 Using GRI/EPA Study

The first step in estimating methane emissions from natural gas systems was to develop a detailed base year estimate of emissions. The study by GRI/EPA (1996) divides the industry into four stages to construct a detailed emission inventory for the year 1992. These stages include: field production, processing, transmission and storage (i.e., both underground and liquefied gas storage), and distribution. This study produced emission factors and activity data for over 100 different emission sources within the natural gas system. Emissions for 1992 were estimated by multiplying activity levels by emission factors for each system component and then summing by stage. Since publication, the EPA has updated activity data for some of the components in the system. Table F-1 displays the 1992 GRI/EPA activity levels and emission factors for venting and flaring from the field production stage, and the current EPA activity levels and emission factors. These data are shown to illustrate the kind of data used to calculate emissions from all stages.

Step 2: Collect Aggregate Statistics on Main Driver Variables

As detailed data on each of the over 100 sources were not available for the period 1990 through 1999, activity levels were estimated using aggregate statistics on key drivers, including: number of producing wells (IPAA 1990 through 1998, EIA 1998), number of gas plants (AGA 1990 through 1998; *OGJ* 1999, 2000), miles of transmission pipeline (OPS 1998, 1999), miles of distribution pipeline (AGA 1990 through 1999), miles of distribution services (AGA 1990 through 1999), and energy consumption (EIA 1998, 1999, 2000). Data on the distribution of gas mains by material type was not available for certain years from AGA. For those years, the average distribution by type was held constant. Table F-2 provides the activity levels of some of the key drivers in the natural gas analysis.

Step 3: Estimate Emission Factor Changes Over Time

For the period 1990 through 1995, the emission factors were held constant, based on 1992 values. An assumed improvement in technology and practices was estimated to reduce emission factors by 5 percent by the year 2020. This assumption, annualized, amounts to a 0.2 percent decline in the 1996 emission factor, a 0.4 percent decline in the 1997 emission factor, a 0.6 percent decline in the 1998 emission factor and a 0.8 percent decline in the 1999 emission factor, all relative to 1995 emission factors.

Step 4: Estimate Emissions for Each Year and Stage

Emissions from each stage of the natural gas industry were estimated by multiplying the activity factors by the appropriate emission factors, summing all sources for each stage, and then subtracting the Natural Gas STAR emission reductions, as reported by industry STAR Partners. Total emissions were estimated by adding the emission estimates from each stage. Table F-3 illustrates emission estimates for venting and flaring emissions from the field production stage using this methodology.

Table F-1: 1992 Data and Emissions (Mg) for Venting and Flaring from Natural Gas Field Production Stage

Activity	GRI/EPA Values			EPA Adjusted Values		
	Activity Data	Emission Factor	Emissions	Activity Data	Emission Factor	Emissions
Drilling and Well Completion						
Completion Flaring	844 compl/yr	733 Scf/comp	12	400 compl/yr	733 scf/comp	6
Normal Operations						
Pneumatic Device Vents	249,111 controllers	345 Scfd/device	602,291	249,111 controllers	345 scfd/device	602,291
Chemical Injection Pumps	16,971 active pumps	248 Scfd/pump	29,501	16,971 active pumps	248 scfd/pump	29,502
Kimray Pumps	11,050,000 MMscf/yr	368 Scf/MMscf	78,024	7,380,194 MMscf/yr	992 scf/MMscf	140,566
Dehydrator Vents	12,400,000 MMscf/yr	276 Scf/MMscf	65,608	8,200,215 MMscf/yr	276 scf/MMscf	43,387
Compressor Exhaust Vented						
Gas Engines	27,460 MMHPhr	0.24 Scf/HPhr	126,536	27,460 MMHPhr	0.24 scf/HPhr	126,535
Routine Maintenance						
Well Workovers						
Gas Wells	9,392 w.o./yr	2,454 scfy/w.o.	443	9,392 w.o./yr	2,454 scfy/w.o.	443
Well Clean Ups (LP Gas Wells)	114,139 LP gas wells	49,570 scfy/LP well	108,631	114,139 LP gas wells	49,570 scfy/LP well	108,631
Blowdowns						
Vessel BD	255,996 vessels	78 scfy/vessel	383	242,306 vessels	78 scfy/vessel	363
Pipeline BD	340,000 miles (gath)	309 scfy/mile	2,017	340,200 miles (gath)	309 scfy/mile	2,018
Compressor BD	17,112 compressors	3,774 scfy/comp	1,240	17,112 compressors	3,774 scfy/comp	1,240
Compressor Starts	17,112 compressors	8,443 scfy/comp	2,774	17,112 compressors	8,443 scfy/comp	2,774
Upsets						
Pressure Relief Valves	529,440 PRV	34.0 scfy/PRV	346	529,440 PRV	34.0 scfy/PRV	346
ESD	1,115 platforms	256,888 scfy/plat	5,499	1,372 platforms	256,888 scfy/plat	6,767
Mishaps	340,000 miles	669 scfy/mile	4,367	340,200 miles	669 scfy/mile	4,370

Table F-2: Activity Factors for Key Drivers

Variable	Units	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Transmission Pipelines Length	miles	292,016	293,862	291,468	293,263	301,545	296,947	292,165	293,187	300,377	300,377
Wells											
GSAM Appalachia Wells*	# wells	120,162	121,586	123,685	124,708	122,021	123,092	122,700	120,064	117,322	117,322
GSAM N Central Associated Wells*	# wells	3,862	3,890	3,852	3,771	3,708	3,694	3,459	3,409	3,361	3,361
GSAM N Central Non-Associated Wells*	# wells	3,105	3,684	4,317	4,885	5,813	6,323	7,073	6,701	8,664	8,664
GSAM Rest of US Wells*	# wells	145,100	147,271	152,897	156,568	160,011	164,750	173,928	173,550	190,387	190,387
GSAM Rest of US Associated Wells*	# wells	256,918	262,441	253,587	249,265	248,582	245,338	246,598	264,385	253,298	253,298
Appalach. + N. Central Non-Assoc. + Rest of US	# wells	268,367	272,541	280,899	286,161	287,845	294,165	303,701	300,315	316,373	316,373
Platforms											
Gulf of Mexico Off-shore Platforms	# platforms	3,798	3,834	3,800	3,731	3,806	3,868	3,846	3,846	3,963	3,975
Rest of U.S. (offshore platforms)	# platforms	24	24	24	24	23	23	24	23	23	23
N. Central Non-Assoc. + Rest of US Wells	# platforms	148,205	150,955	157,214	161,453	165,824	171,073	181,001	180,251	199,051	199,051
Gas Plants											
Number of Gas Plants	# gas plants	761	734	732	726	725	675	623	615	558	581
Distribution Services											
Steel – Unprotected	# of services	5,500,993	5,473,625	5,446,393	5,419,161	5,392,065	5,365,105	5,388,279	5,361,338	5,361,338	5,361,338
Steel - Protected	# of services	19,916,202	20,352,983	20,352,983	20,512,366	20,968,447	21,106,562	21,302,429	22,850,283	22,865,354	22,865,354
Plastic	# of services	16,269,414	17,654,006	17,681,238	18,231,903	19,772,041	20,270,203	20,970,924	26,396,310	26,480,252	26,480,252
Copper	# of services	228,240	233,246	233,246	235,073	240,299	241,882	244,127	261,865	262,038	262,038
Total	# of services	41,914,849	43,713,860	43,713,860	44,398,503	46,372,852	46,983,752	47,905,759	54,869,796	54,968,982	54,968,982
Distribution Mains											
Steel – Unprotected	miles	91,267	90,813	90,361	89,909	89,460	89,012	88,567	88,125	87,684	87,684
Steel – Protected	miles	491,120	492,887	496,839	501,480	497,051	499,488	468,833	463,975	467,016	467,016
Cast Iron	miles	52,644	52,100	51,800	50,086	48,542	48,100	47,100	47,900	48,800	48,800
Plastic	miles	202,269	221,600	244,300	266,826	284,247	294,400	329,700	355,300	377,300	377,300
Total	miles	837,300	857,400	883,300	908,300	919,300	931,000	934,200	955,300	980,800	980,800

* GSAM (Gas Systems Analysis Model) is a natural gas supply, demand, and transportation model used by the Federal Energy Technology Center of the U.S. Department of Energy (GSAM 1997).

Table F-3: CH₄ Emission Estimates for Venting and Flaring from the Field Production Stage (Mg)

Activity	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Drilling and Well Completion										
Completion Flaring	5.4	5.5	5.6	5.7	5.8	5.9	6.1	6.0	6.3	6.3
Normal Operations										
Pneumatic Device Vents	567,778	578,313	602,291	618,531	635,276	655,386	692,033	687,785	757,995	756,470
Chemical Injection Pumps	36,449	37,323	39,053	40,277	41,668	43,111	45,666	45,256	50,352	50,251
Kimray Pumps	134,247	136,380	140,566	143,211	144,040	147,191	151,572	149,506	157,056	156,740
Dehydrator Vents	41,436	42,095	43,387	44,203	44,459	45,432	46,784	46,146	48,477	48,379
Compressor Exhaust Vented Gas Engines	119,284	121,498	126,535	129,947	133,465	137,690	145,389	144,497	159,247	158,927
Routine Maintenance										
Well Workovers Gas Wells	531	540	556	567	570	582	600	591	621	620
Well Clean Ups (LP Gas Wells)	101,118	102,725	105,878	107,870	108,494	110,868	114,168	112,612	118,299	118,061
Blowdowns										
Vessel BD	256	261	271	278	284	292	306	303	329	328
Pipeline BD	1,710	1,729	1,772	1,799	1,818	1,852	1,908	1,894	1,996	1,992
Compressor BD	1,548	1,573	1,627	1,662	1,687	1,730	1,802	1,786	1,919	1,915
Compressor Starts	3,462	3,518	3,640	3,718	3,773	3,871	4,031	3,995	4,292	4,284
Upsets										
Pressure Relief Valves	326	332	346	355	365	376	397	395	435	434
ESD	6,764	6,827	6,767	6,646	6,773	6,882	6,834	6,816	7,006	7,013
Mishaps	925	936	959	974	984	1,003	1,033	1,025	1,080	1,078